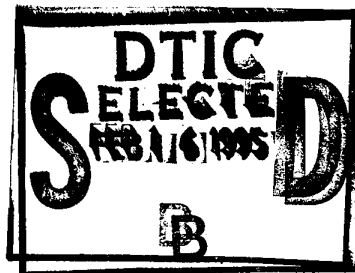


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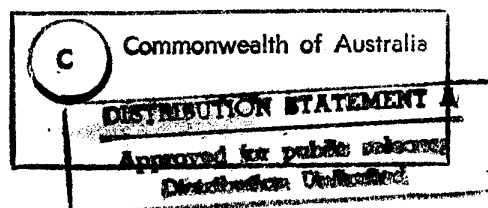
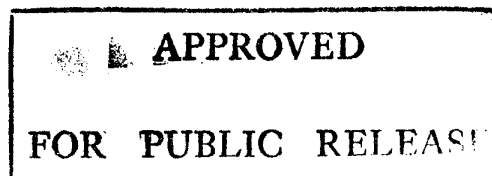
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The Distribution of Snapping
Shrimp Noise Near Gladstone,
Queensland

Mark Readhead

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The Distribution of Snapping Shrimp Noise Near Gladstone, Queensland

Mark Readhead

Maritime Operations Division
Aeronautical and Maritime Research Laboratory

DSTO-TR-0047

ABSTRACT

The intensity of the noise generated by snapping shrimp between 630 and 12 500 Hz was measured from Auckland Wharf to the end of the dredged channel leading into Gladstone, Queensland, and on a route out across to the edge of the reef. Within the channel the noise was recorded every nautical mile; out across the reef the stations were five miles apart. Intense snapping shrimp noise was found at all sites.

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The Distribution of Snapping Shrimp Noise near Gladstone, Queensland

EXECUTIVE SUMMARY

Snapping shrimp are commonly found on sea bottoms composed of sheltering materials such as rock and coral, in waters of less than 55 m depth where the water temperature exceeds 11°C for much of the year. By snapping closed its large claw the shrimp makes a loud sound. When the shrimp are gathered in large numbers the superposition of these sounds leads to a sustained background noise.

When viewed on a mine hunting sonar screen, the snaps appear as flashes which can form a background clutter, making mine detection difficult. To determine whether this is likely to be a problem in typical mine hunting locations in Australia, a survey was conducted to measure the distribution of snapping shrimp noise within and near a typical harbour. Waters in the vicinity of Gladstone, Queensland, were chosen, and the intensity of the noise generated by the shrimp was measured every nautical mile from Auckland Wharf to the end of the dredged channel leading into the port. Further recordings were taken in five mile steps across Curtis Channel to the edge of the Great Barrier Reef.

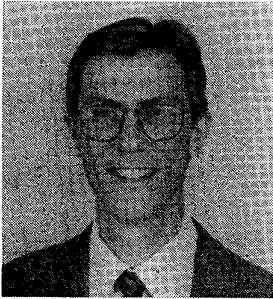
The data was analysed between 630 and 12 500 Hz, and showed intense broadband snapping shrimp noise at all sites. The intensity was higher in the harbour and dredged channel than out across the reef. Within the harbour and channel the noise exceeds that which would be expected from wind generated noise during a sea state of 7. Across the reef the noise exceeds sea state 3 wind generated noise. It is anticipated that the snaps should be evident on a mine hunting sonar screen at all sites investigated in this study.

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Author

Mark Readhead

Maritime Operations Division



Mark Readhead obtained a BSc(Hons) in Physics from the University of Western Australia in 1979, and a PhD in Physics from the Australian National University in 1984. After lecturing in Physics and holding the position of Postdoctoral Research Associate at the University of Washington, he joined DSTO in 1989. He works with the sonar group of the Maritime Operations Division and current research interests include the performance of fluid-filled spherical shells, target strengths of sea mines, absorption of sound by sea water, and the distribution of underwater noise sources.

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1. Introduction

Snapping shrimp (*Alpheus* and *Synalpheus* spp.) are commonly found on sea bottoms composed of rock, shell, coral or other sheltering materials, in waters of less than 55 m depth where the water temperature exceeds 11°C for the greater part of the year (Everest *et al.*, 1948). By snapping closed its large claw the shrimp makes a loud impulsive click with a broad frequency response from tens of hertz to hundreds of kilohertz. The sound has been identified with snapping shrimp by placing several in a vessel of water in the laboratory (Everest *et al.*, 1948). When the shrimp are gathered in large numbers the superposition of these sound impulses leads to a sustained background noise, sounding like a distinctive frying noise (Everest *et al.*, 1948; Widener, 1967), which above several hundred hertz, in the absence of rain generated noise, is often the dominant source of ambient noise.

When viewed on a mine hunting sonar screen, the snaps manifest themselves as highlights randomly appearing and disappearing with each ping. They can appear in such numbers as to form a background clutter which can make mine detection difficult. To determine the likelihood of this being a problem in typical mine hunting locations in Australia, a survey was conducted to measure the distribution of snapping shrimp noise within and near a typical harbour. For this work, waters in the vicinity of Gladstone, Queensland, were chosen.

2. Survey Location

The route of the survey was from alongside Auckland Wharf in Gladstone harbour, out along the dredged channel to the furthest pair of channel markers, S1 and S2, marking the approach to Gladstone harbour. Over much of this route the pairs of markers occurred at regular intervals of 0.6 nautical miles, so to take advantage of their known locations, measurements were taken between each second pair. That is, each 1.2 nautical miles. The actual locations are shown in Fig. 1.

It had been intended to continue the survey every nautical mile in a straight line from S1 and S2 out to 23° 49.9' S and 151° 35.0' E, and from thence in five nautical mile steps out across Curtis Channel to 24° 01.2' S and 152° 44.3' E, but a large portion of this intended route was not covered due to inclement weather. However, the section from 23° 54.6' S and 152° 1.2' E to 24° 1.3' S and 152° 42.9' E was measured. The actual locations are shown in Fig. 2.

Fig. 3 shows a cross-section of the entire track, indicating the water depth and sample positions. As the snapping shrimp are bottom dwelling creatures, the depth below a hydrophone is a measure of the distance from the noise source to the receiving hydrophone.

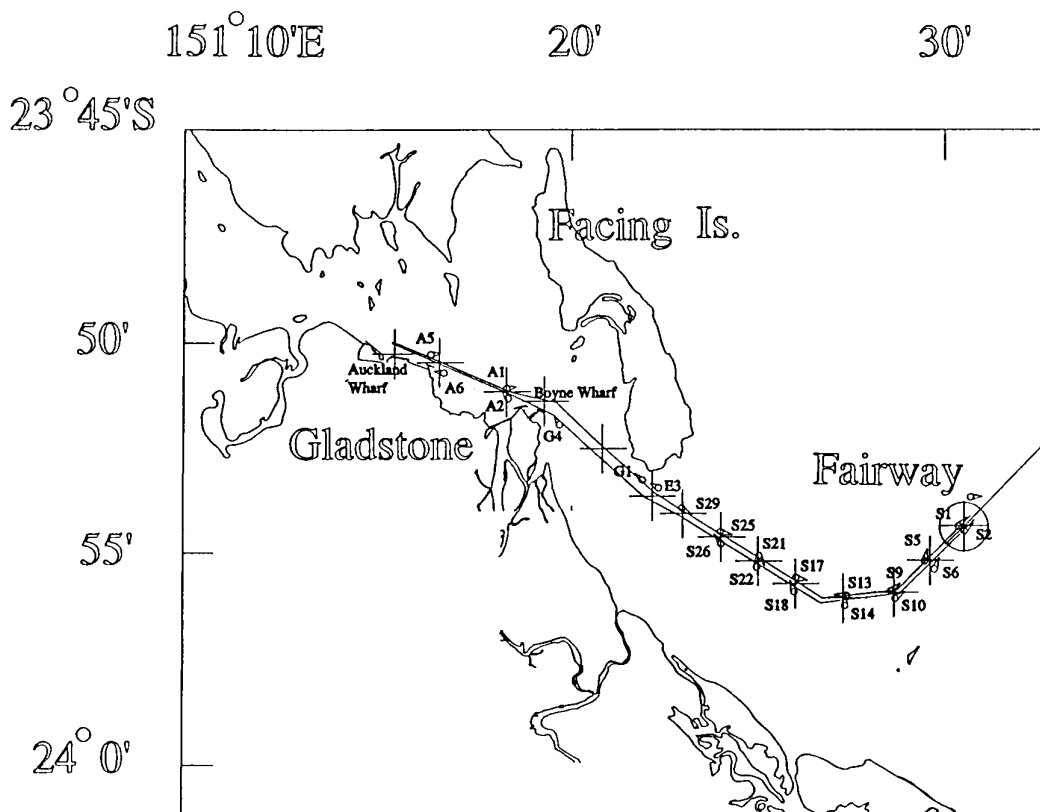


Figure 1: Gladstone harbour and channel sample locations. The sample locations are marked with a cross. Those beacons from Auckland wharf to the fairway marker which were close to the sample sites are shown. Also marked is the dredged approach channel to the harbour.

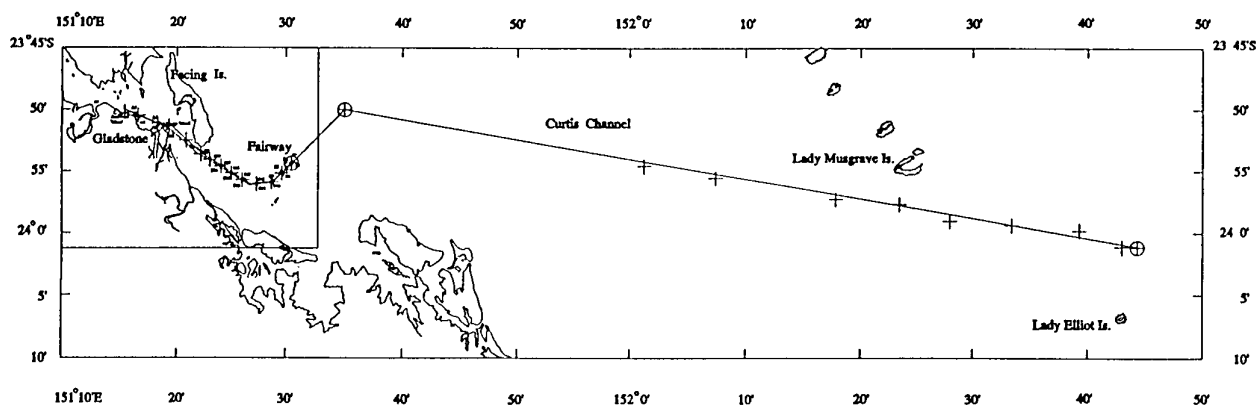


Figure 2: Sample locations across Curtis Channel to the edge of the Great Barrier Reef off Gladstone. The crosses mark the sample locations. The crosses surrounded by circles are not sample sites, but represent the end points of the track.

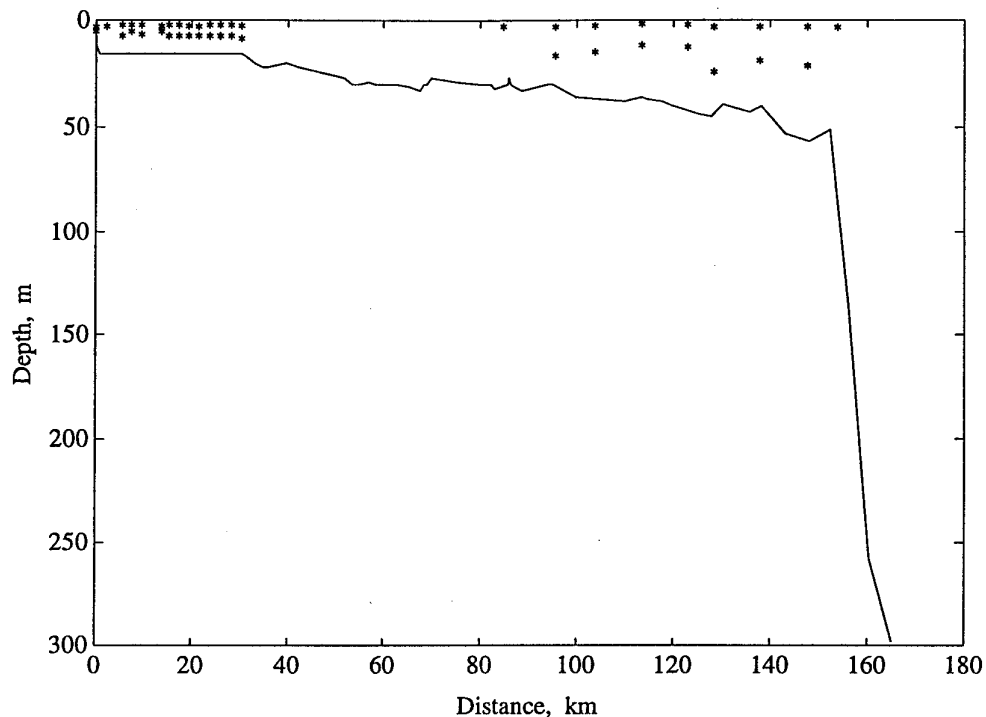


Figure 3: Cross-section of the survey route. The asterisks mark hydrophone depths; the solid curve represents the sea floor.

3. Experimental Procedure

3.1 Equipment

The equipment used to record the snapping shrimp noise was simple. Fig. 4 is a block diagram of it. The receiving hydrophone was an omnidirectional Clevite CH17 attached to a 30 m coaxial cable. The 3 m of the cable closest to the hydrophone was wrapped with string to reduce flow noise. To reduce the intensity of the incoming signal below 2 kHz, it was passed through a simple passive filter consisting of an 18 k Ω resistor which was placed in parallel with the hydrophone capacitance. After this the line was split in two, with each being amplified by a Maritime Operations Division designed and built low noise preamplifier. Usually the gains were set to 20 and 40 dB. After amplification the two signals were sent to a Sony Walkman WM60 Audio Professional Recorder on which the record level was set to 5. On such a setting little extra gain was added. The stereo signals were recorded on TDK SA-X90 tapes.

To monitor the incoming signals either Sony MDR-51 Dynamic Stereo Headphones or a pair of AIWA SC-A7 Compact Speaker System speakers were used.

The signal which received only 20 dB of gain was of similar intensity to the tape noise, so was not used for the primary analysis. It was recorded in the event particularly loud snaps occurred which with 40 dB of gain might overload the recording system. This did not turn out to be a problem, so all the analysis was undertaken with the 40 dB amplified signal.

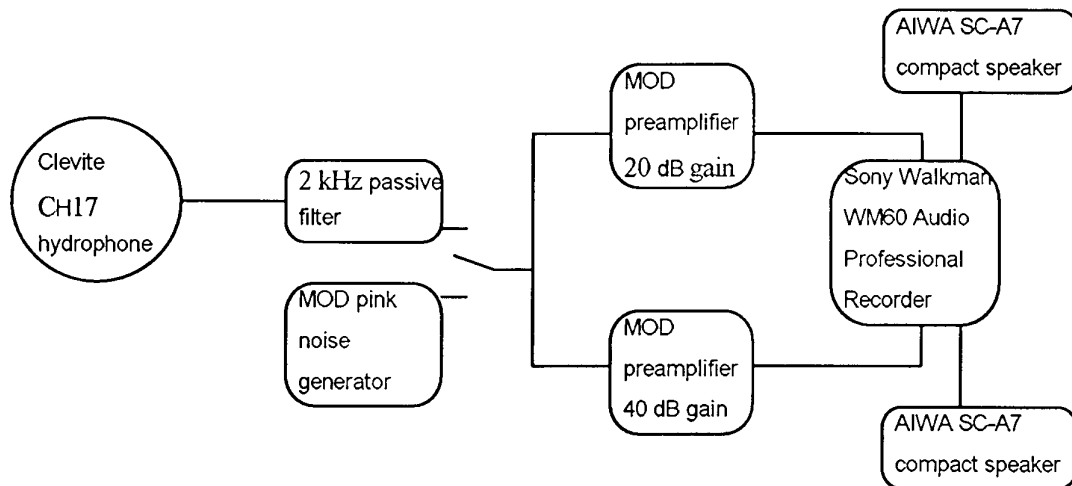


Figure 4: Block diagram of the recording equipment.

3.2 Calibrations

The hydrophone was calibrated at Woronora Dam using the arrangement shown in Fig. 5. A Weston C1016 transducer was used as sound projector and was lowered to 20 m depth. Also lowered to the same depth and forming the corners of a 3 m equilateral triangle with the Weston C1016 projector were the Clevite CH17 hydrophone and an ITC 1032 hydrophone. The latter was well calibrated and acted as a reference hydrophone. At each of a set number of frequencies a current of 100 mA peak-to-peak was sent to the Weston C1016 projector, having been generated by an HP 3314A function generator and passed through a Bose 1801 power amplifier and Maritime Operations Division hydrophone tuning inductor. The signals were picked up by the two receivers. In the case of the Clevite CH17 hydrophone, the signal was passed through the same 2 kHz filter as used for the measurements near Gladstone. Both signals were then amplified by 40 dB using Maritime Operations Division designed and built preamplifiers. They then passed to an Ithaco 4211 filter set to pass two-thirds of an octave either side of the test frequency, and onto an Analogic Data Precision Data 6000 universal waveform analyser. On the latter instrument the peak-to-peak voltages from each receiver were compared, and the Clevite CH17 sensitivity calculated. The result is shown in Fig. 6.

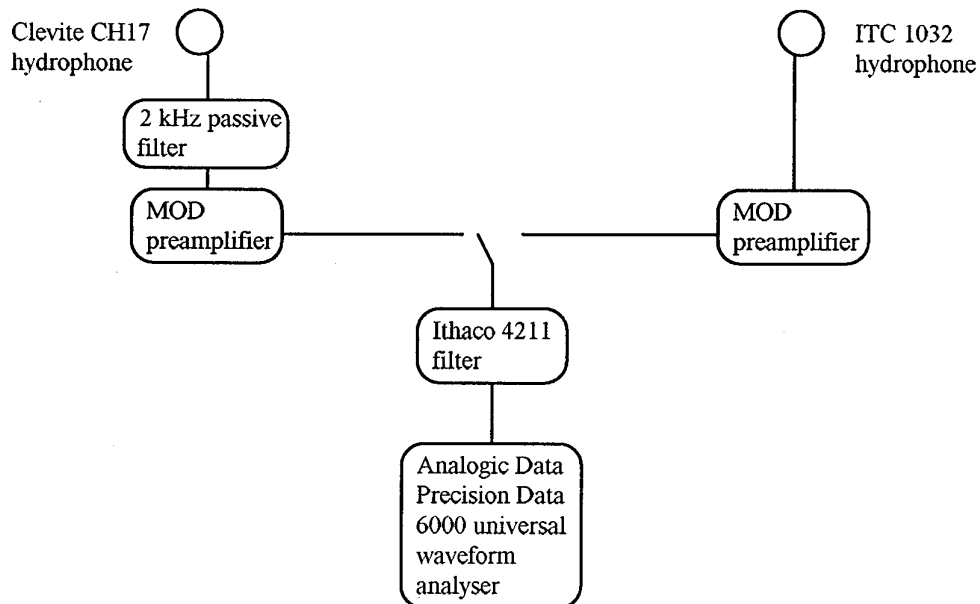
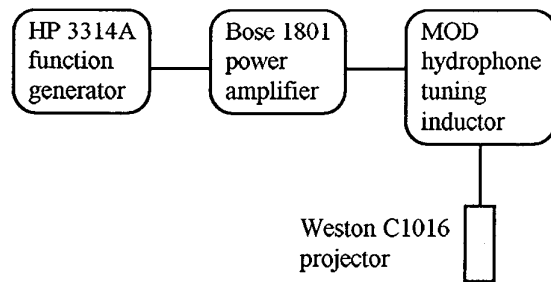


Figure 5: Experimental arrangement for the hydrophone calibration.

To calibrate the preamplifiers an HP 3562A dynamic signal analyser was used. It generated a sinusoidal signal which was slowly swept from 100 Hz to 20 kHz. This signal was input directly into one channel; the other channel was fed the signal after amplification by the preamplifier. A comparison of the two channels gave the gain as a function of frequency.

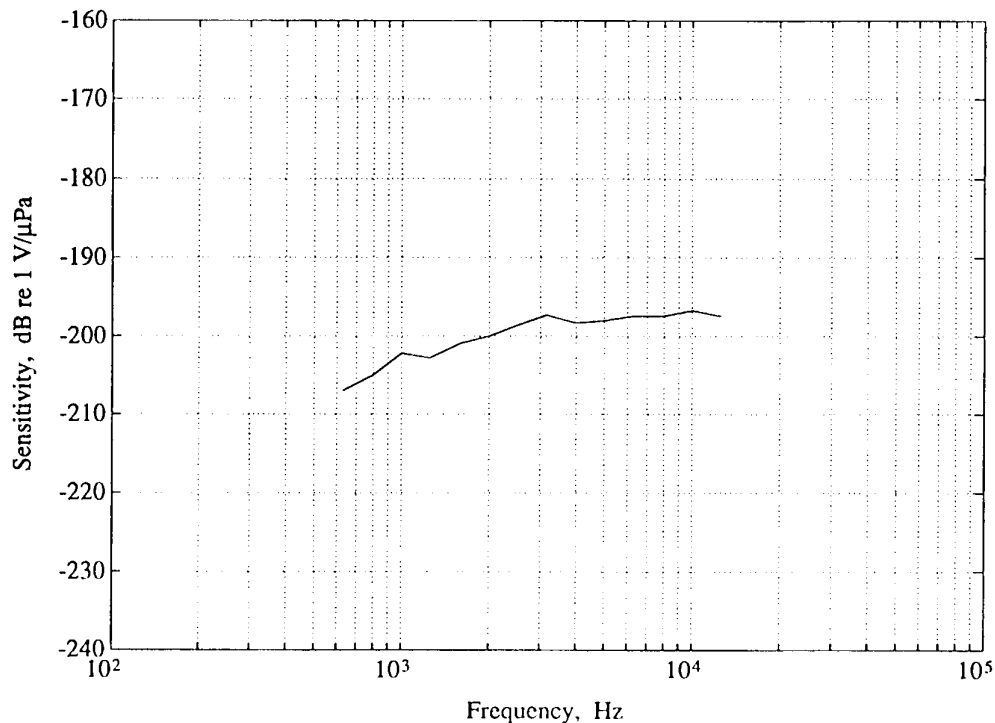


Figure 6: Sensitivity of the Clevite CH17 hydrophone.

Throughout the course of the measurements the recording system, from preamplifiers through to tape recorder and tape were calibrated by feeding in a known signal from a Maritime Operations Division designed and built pink noise generator. The noise level chosen was -130 dB re 1 V²/Hz at 1 kHz, which was similar to the level of snapping shrimp noise as output by the Clevite CH17 hydrophone. This calibration signal was laid down on the tape after every few recordings in order to correct for any possible drift in recording gain.

As a check on possible tape recording distortion, pink noise signals from -130 to -100 dB re 1 V²/Hz at 1 kHz were recorded and played back into an HP 3562A dynamic signal analyser. Even though the most intense of these signals was some 40 dB greater than the snapping shrimp intensities recorded off Gladstone, there was no sign of distortion for any of them.

3.3 Procedure

The long distance transits were done on board the AMS Carole-S. As this vessel's engines could not be shut down whilst at sea, it was necessary to record the data away from it. To this end a Zodiac was launched and the Maritime Operations Division personnel went in it with the equipment in a waterproof housing, and a coxswain supplied by the ship. The boat moved $\frac{1}{2}$ -1 nautical mile from the Carole-S and a radar reflector was hoisted so the ship could get a radar fix on the Zodiac's position. At the same time the ship's depth sounder was switched off, so as not to interfere with the measurements.

Depending on when the last pink noise calibration was recorded, this was done, and then the Clevite CH17 hydrophone was lowered over the side of the Zodiac and recording commenced. The incoming noise was recorded for 5 min. at a depth of 3 m, and then the hydrophone was lowered to mid-water depth and another 5 min. was recorded. On each occasion the angle the cable made with the water surface was noted, so the actual depth could be determined later. Care was taken to ensure the hydrophone cable did not scrape against the side of the boat during recording. During the recording the incoming sound was monitored to confirm that the distinctive frying noise associated with snapping shrimp was what was being recorded. Any extraneous noises, such as whale songs, were noted, so that portion of the tape could be avoided in the subsequent analysis.

At the completion of the measurements the hydrophone was recovered and the Zodiac and Carole-S transitted to the next station. For the measurements taken in the dredged channel, the Carole-S did not accompany the Zodiac from one station to the next, but kept its distance.

The order in which the results are presented below do not reflect the order in which they were taken. Groups of stations were measured to take advantage of weather conditions. A number of intended stations from between the channel markers S1 and S2 out to $23^{\circ} 54.6' S$ and $152^{\circ} 1.2' E$ were not measured because on each attempt the conditions were too rough to safely launch and recover the Zodiac.

4. Analysis

The data was analysed using B&KNOISE, a software package written by Tavener (in press). It is intended to be used in conjunction with a Brüel and Kjaer 2131 spectrum analyser, which it controls according to input choices made by the user. The spectrum analyser was set to average the noise recorded in one third octave bands centred from 630 to 12,500 Hz, using 8 samples of 16 s each. The sea noise in each band was calculated according to

$$SN = B\&K_{out} - Cal_{rec} + Cal_{exp} + BW_1 - HP - PreG - BW_2 \quad (1)$$

where

SN	is the sea noise in dB re $1\mu Pa^2/Hz$,
$B\&K_{out}$	is the output from the spectrum analyser for the sample of sea noise in dB re $1\mu V$,
Cal_{rec}	is the output from the spectrum analyser for the calibration sample of pink noise in dB re $1\mu V$,
Cal_{exp}	is the pink noise calibration level in dB re $1 V^2/Hz$ at 1 kHz,
BW_1	is the bandwidth correction needed to convert the per Hz value of Cal_{exp} to the per one third octave values of Cal_{rec} ,
HP	is the hydrophone sensitivity in dB re $1 V/\mu Pa$,
PreG	are other gains (in dB) in the system not included in the above variables, and
BW_2	is the bandwidth correction needed to return the values to per Hz values.

For a pink noise calibration signal the spectrum level per one third octave is constant and equal to the value for the one third octave centred on 1 kHz, so

$$BW_1 = 10 \log_{10}(0.23 \times 1000). \quad (2)$$

The other bandwidth correction is given by

$$BW_2 = 10 \log_{10}(0.23 \times \text{one third octave centre frequency}). \quad (3)$$

PreG is the gain of the preamplifier and was 40 dB for the analysis reported below. The mean sea noise and its standard deviation across the 8 samples of 16 s each were then determined and plotted at each one third octave centre frequency.

5. Results

Figs 7 and 8 show noise spectra from 630 to 12 500 Hz as recorded at approximately 3 m depth and mid depth, respectively, at stations in Gladstone harbour and its approach channel. The locations can be viewed in Fig. 1. Figs 9 and 10 show noise spectra over the same frequency range at approximately 3 m depth and mid depth, respectively, across Curtis Channel towards the edge of the reef. The locations are shown in Fig. 2. Also shown in Fig. 7 to 10 are the noise spectra to be expected from wind noise in sea states of approximately 3 and 7 on the Beaufort scale (Cato, 1978).

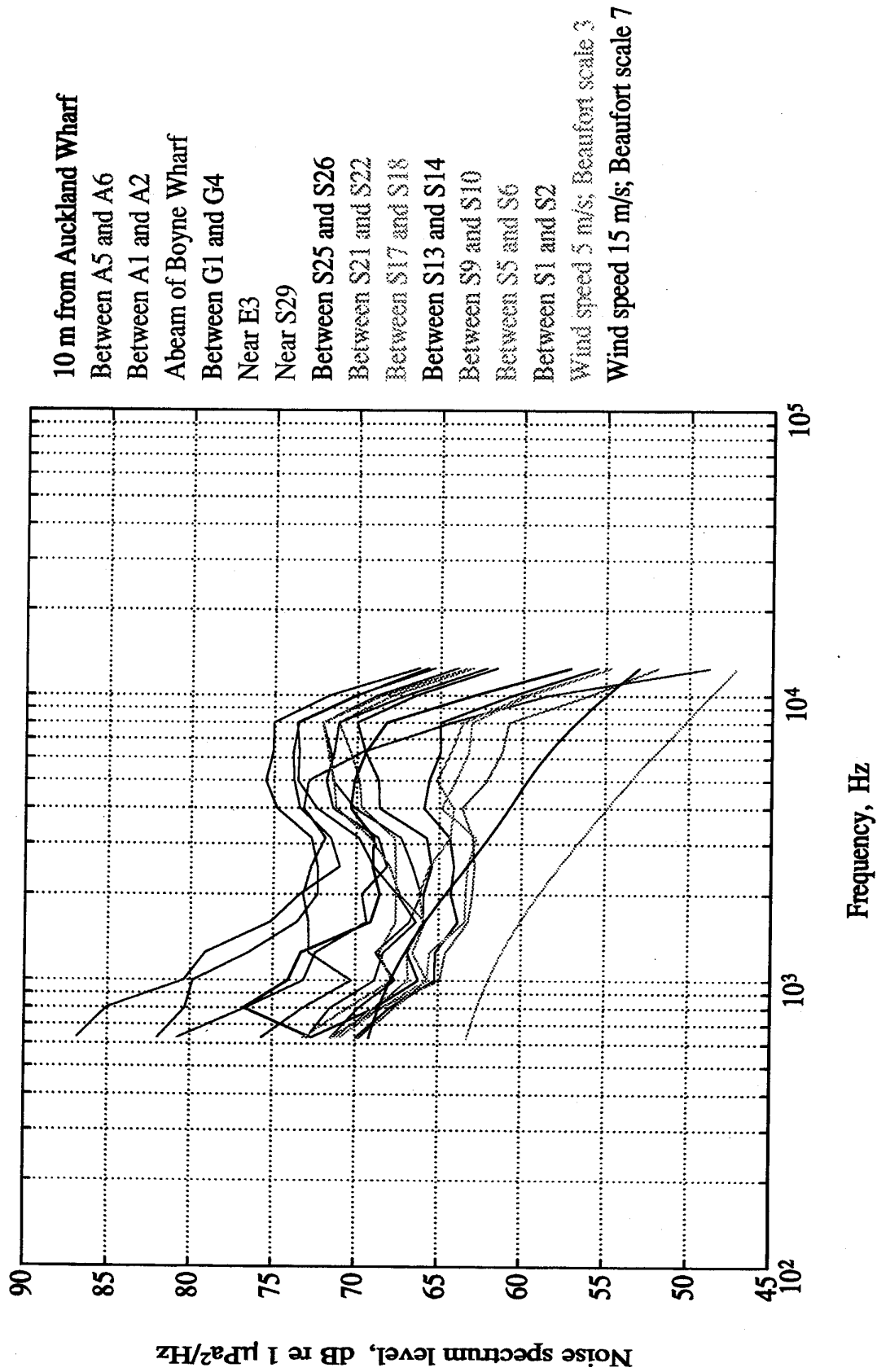


Figure 7: Noise spectra recorded at approximately 3 m depth at stations in Gladstone harbour and channel. Also shown are the curves for noise generated by winds of 5 and 15 m/s.

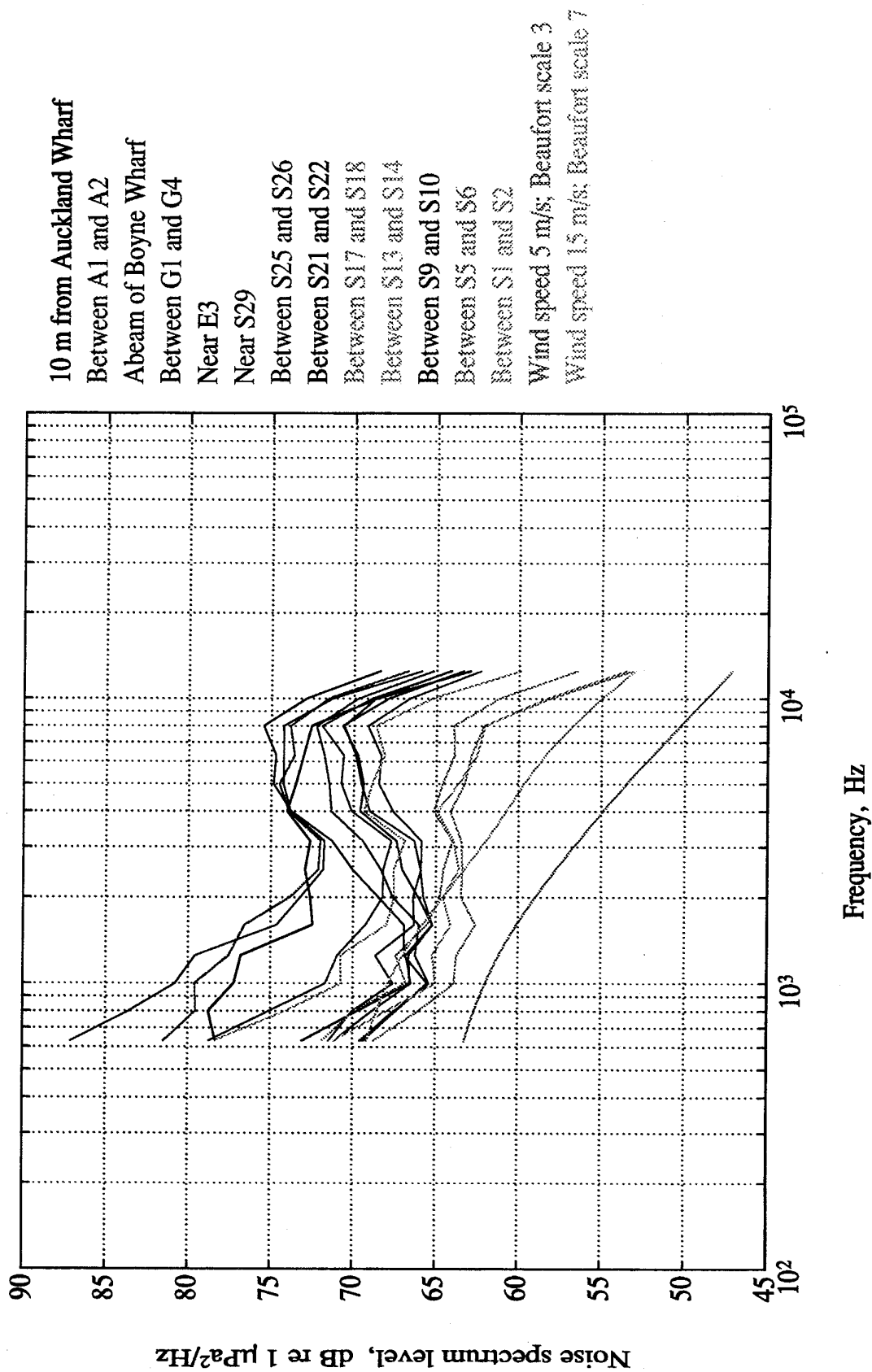


Figure 8: Noise spectra recorded at approximately mid depth stations in Gladstone harbour and channel. Also shown are the curves for noise generated by winds of 5 and 15 m/s.

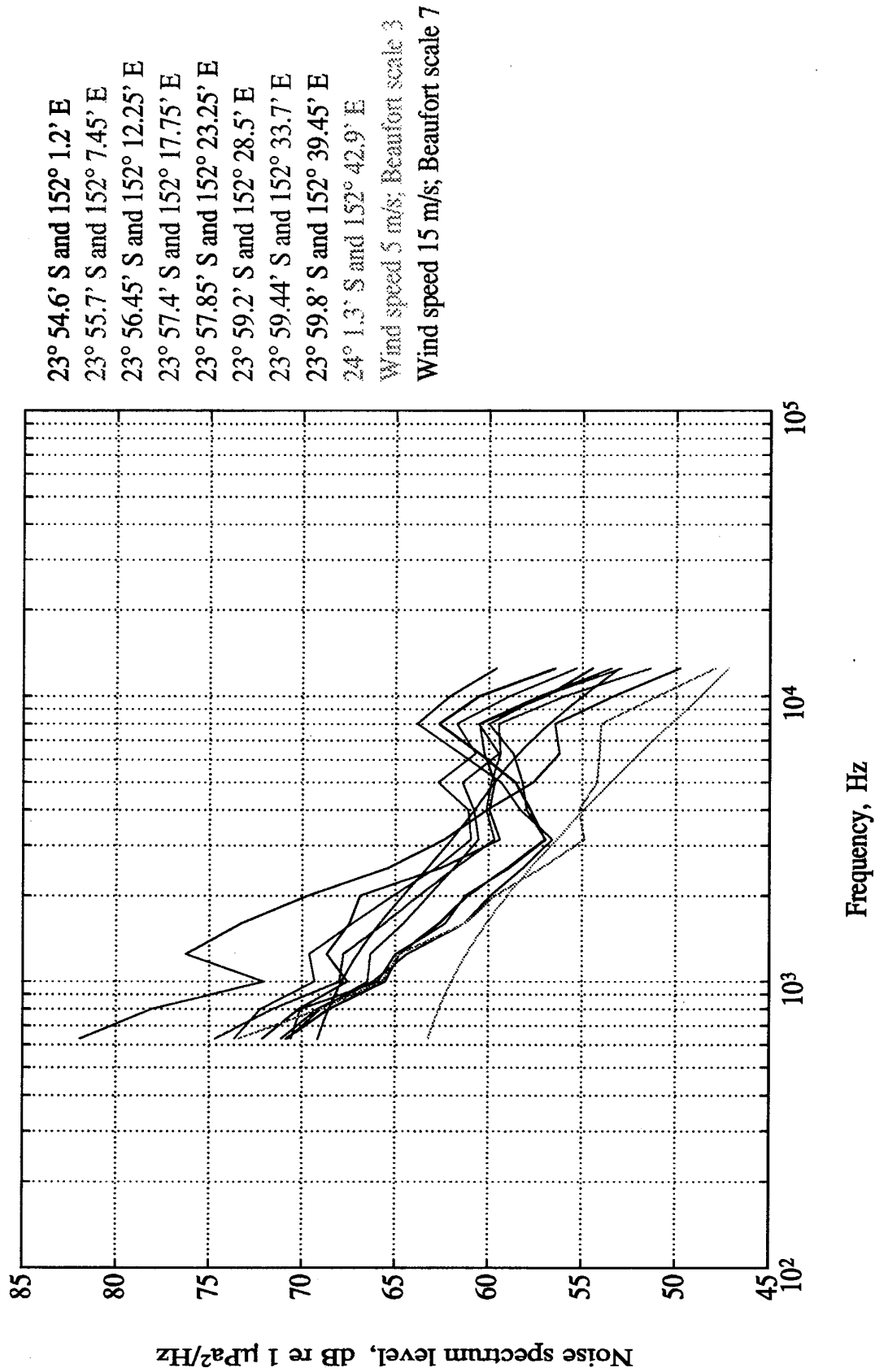


Figure 9: Noise spectra recorded at approximately 3 m depth at stations across Curtis Channel. Also shown are the curves for noise generated by winds of 5 and 15 m/s.

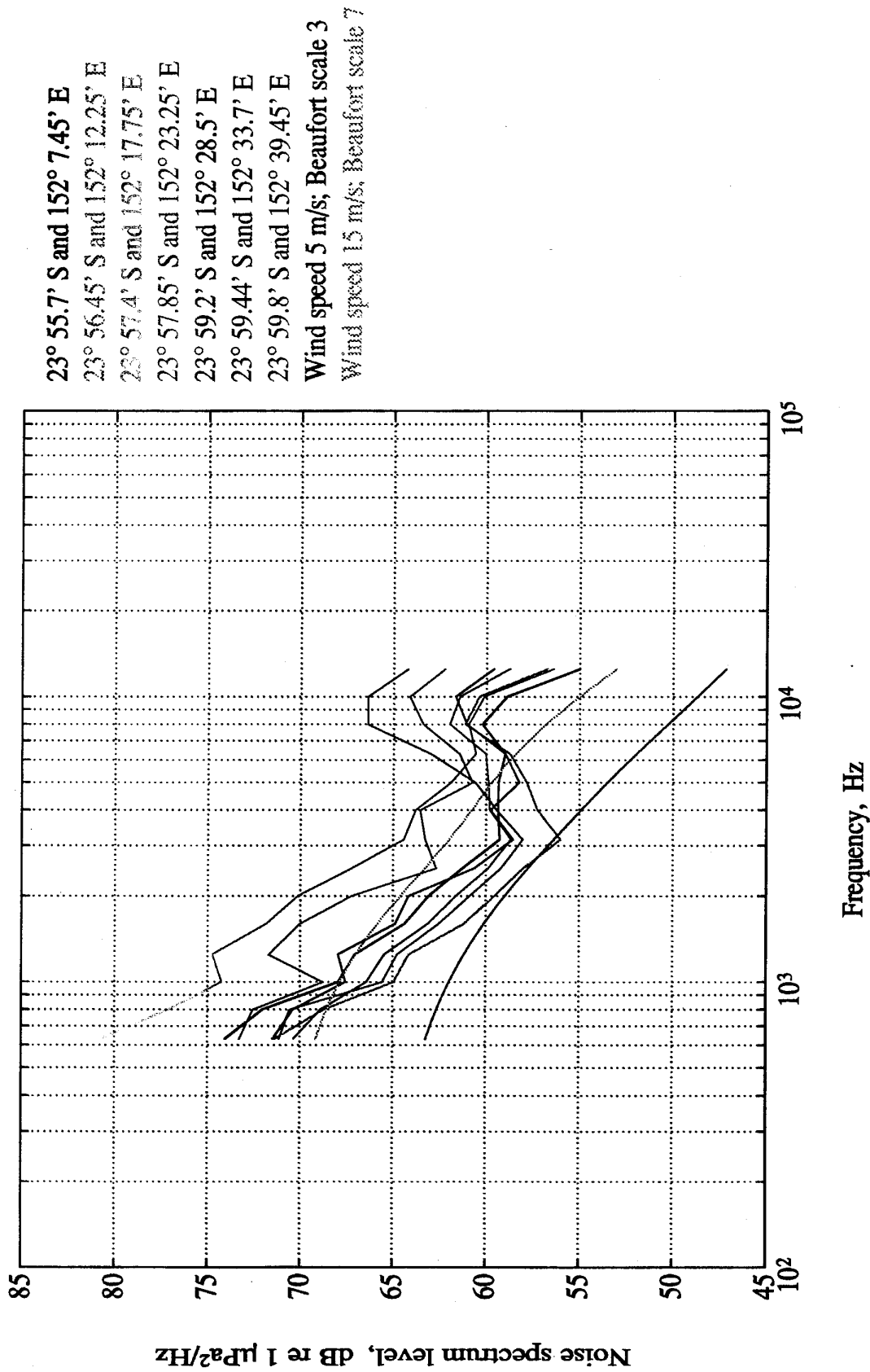


Figure 10: Noise spectra recorded at approximately mid depth at stations across Curtis Channel. Also shown are the curves for noise generated by winds of 5 and 15 m/s.

It should be noted that the spectra display the superposition of all sources of noise as recorded at each site, although where intermittent sources occurred, these were excluded from the analysis. The other non-snapping shrimp sources of noise were generally of minor importance, however, the readings from near the Boyne Wharf had a significant broad frequency source from electrical equipment.

No attempt has been made to correct for the non-achievement of exactly 3 m or mid depth for each of the measurements. As the hydrophone approached the surface it would have been further from the snapping shrimp, so absorption would have lessened the intensity somewhat, but to quantify the effect would require knowledge of the size of the shrimp beds. This was not known. However, given the often small variations in intensity between 3 m depth and mid depth at the one site, the corrections are expected to be minor.

Bearing in mind the above caveats, inspection of Fig. 7 to 10 show that the noise intensities are higher in the harbour and dredged channel than further out across the reef, and generally decrease with distance from the harbour wharfs. Within the harbour and dredged channel the noise also exceeds that which would be expected from wind generated noise during a sea state of 7. Across Curtis Channel the noise levels are lower, but still exceed that from sea state 3 wind generated noise.

Fig. 11 shows the noise spectrum intensity at 5 kHz and water depth versus location within Gladstone harbour and its approach channel and across Curtis Channel. This diagram allows the variation of intensity with location to be seen more clearly at one representative frequency. In the shallower water the level is higher, although rather variable. These variations do not correspond to different water depths, but presumably to the density of snapping shrimp colonies as habitats change. Across Curtis Channel, where the water depth was greater, the noise intensities are lower and more uniform, even though the depth was varying more.

Fig. 12 shows the noise amplitude as a function of time for a 50 ms period. It was recorded between the S13 and S14 channel markers with the hydrophone at 2.1 m depth. The impulsive nature of the snaps is clearly evident. Fig. 13 shows the noise amplitude as recorded at the same site over a 2 ms period. The low frequency components of individual snaps are shown in some detail, but it should be noted that the frequency response of the recording equipment did not extend beyond 16 kHz, so rapid intensity fluctuations are absent. Transients of less than 60 μ s are spread in time and display considerable ringing, so typical snap transients of from 3 to 8 μ s (Cato and Bell, 1992) cannot be detected.

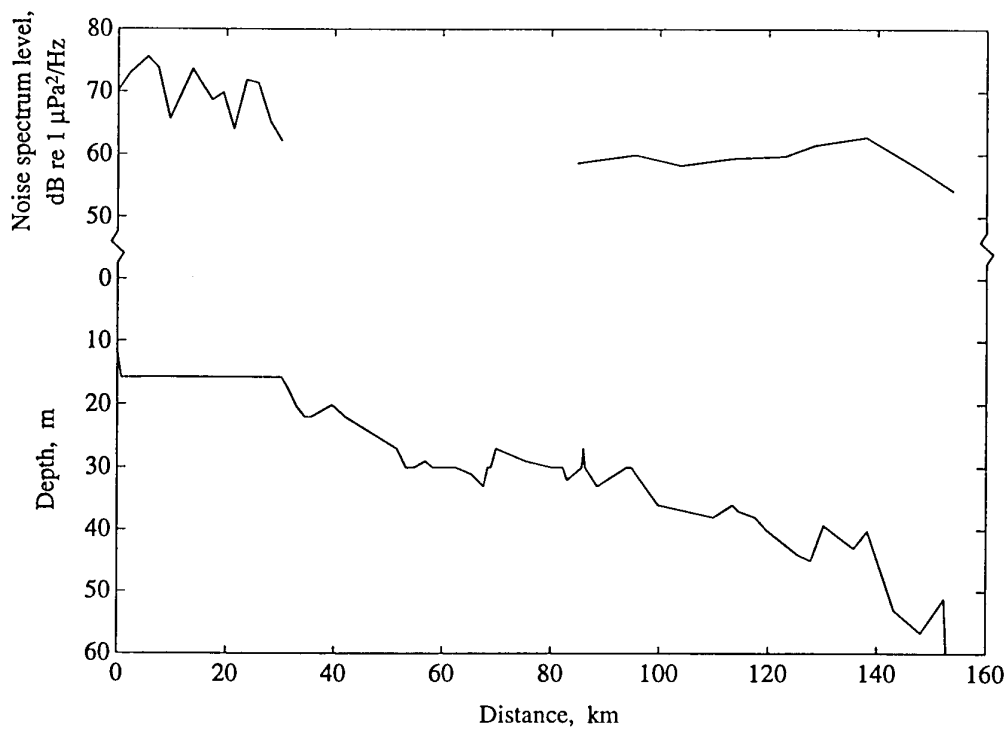


Figure 11: Noise spectrum level at 5 kHz along the survey route. Also shown is the water depth along the route.

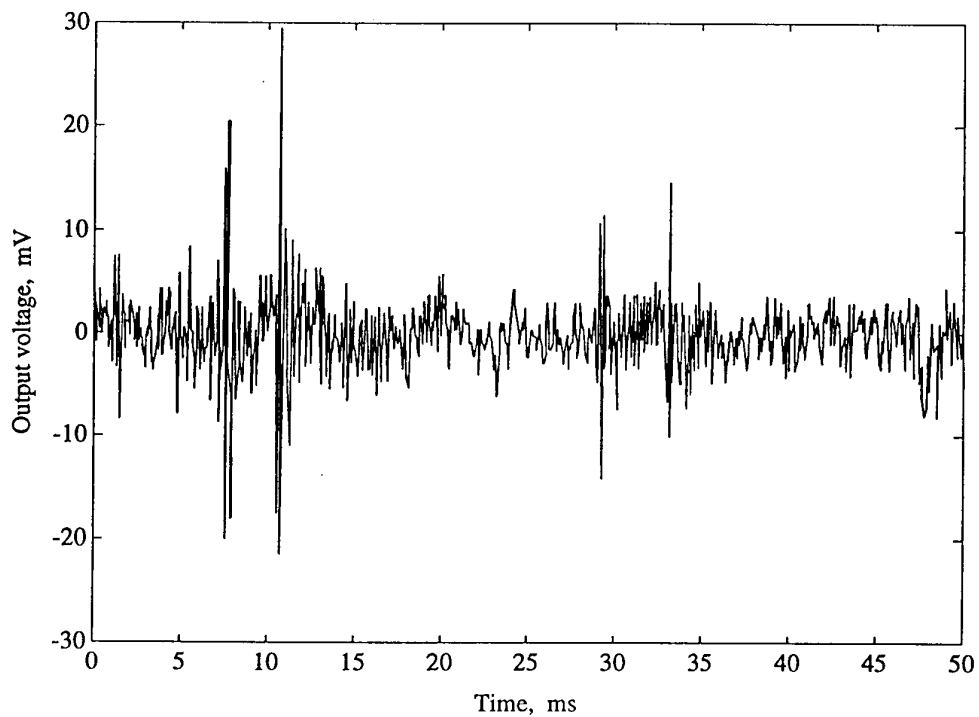


Figure 12: Noise signal as recorded by the tape recorder, after amplification, over 50 ms.

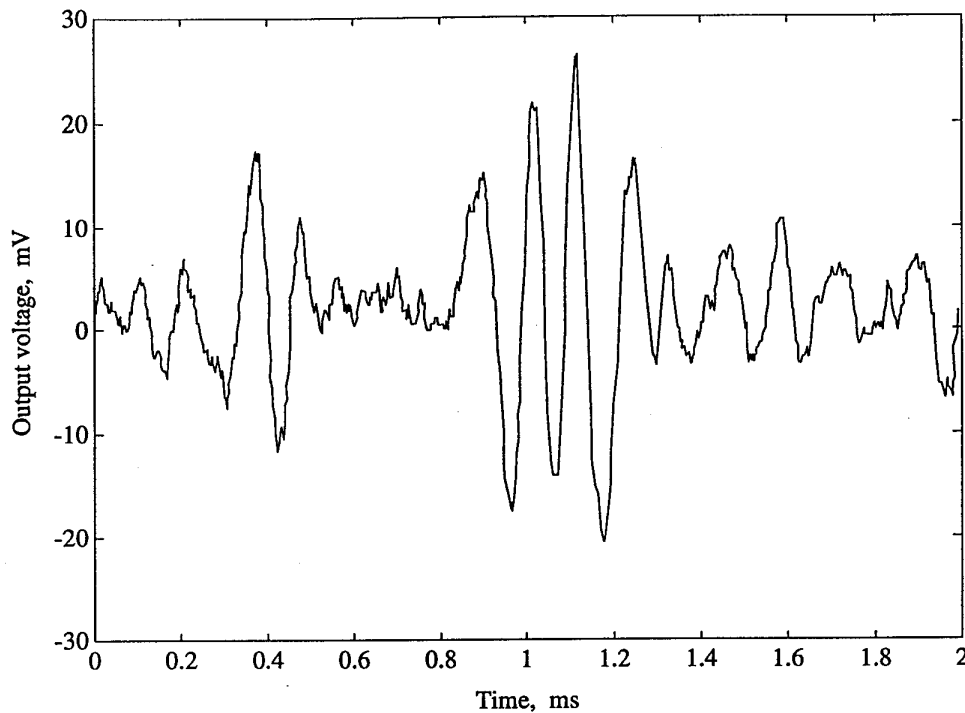


Figure 13: Noise signal as recorded by the tape recorder, after amplification, over 2 ms.

6. Comparisons with Other Data

A comparison with data collected at other locations is shown in Fig. 14. To avoid complicating the diagram, the average noise spectrum levels have been given for all the measurements from Gladstone harbour and its approach channel, and Curtis Channel. To these are added two curves from Cato and Bell (1992), three from Widener (1967), five from Everest *et al.* (1948), as well as the wind generated noise curves.

The data labelled "Cowley Beach" were recorded in a region where rock and coral outcrops were evident in a water depth of about 6 m off Cowley Beach, near Innisfail in Queensland (Cato and Bell, 1992). About 1 km away in 20 m water depth, where the bottom was muddy, they found the noise to be "very much lower ... and not sufficiently above background noise from other sources to make a reliable estimate of its spectral levels". Hence, off Cowley Beach they recorded noise levels both exceeding and less than those off Gladstone.

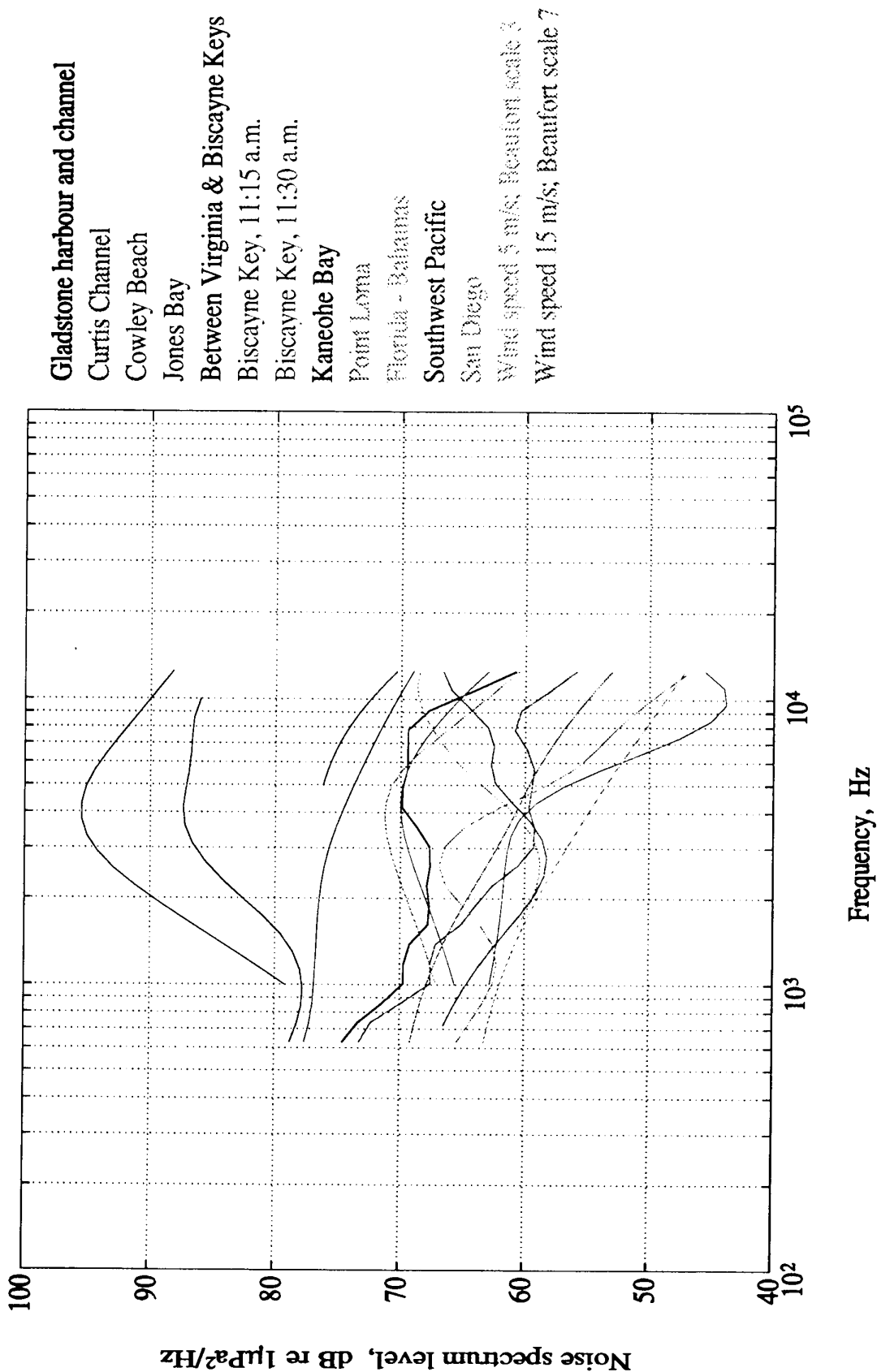


Figure 14: Noise spectra recorded at sites in Australia, the USA, the Bahamas and the southwest Pacific. Also shown are the curves for noise generated by winds of 5 and 15 m/s.

Cato and Bell (1992) also took readings from Jones Bay within Sydney Harbour, and these data are also shown in Fig. 14. In this case the levels are somewhat higher than those from Cowley Beach, and hence are greater than those from Gladstone.

Three sets of data of Widener (1967) are presented. The highest level reported came from the end of a pier between Virginia and Biscayne Keys, Florida, in 3 m water depth. The author noted that the noise sources were distributed; the hydrophone was not located near a concentrated source and the data showed no temporal variation from 1 hr before sunrise to 2 hr after sunset. The levels greatly exceed those near Gladstone.

A little over a mile away, off the lighthouse on Biscayne Key, Widener (1967) measured the snapping shrimp spectra over a 25 min. period. Two of his curves are reproduced in Fig. 14, having been recorded 15 min. apart. Not only are the noise levels between 13 and 47 dB less than off the pier, but change by 2 to 22 dB over this short time interval at the same site. The spectra at the two times are significantly different. Nevertheless, the levels are broadly similar to those recorded off Gladstone.

Five sets of results of Everest *et al.* (1948) are shown in Fig. 14. The spectrum for Kaneohe Bay, Hawaii, is the average of two very consistent spectra taken about a metre from a pier close to shrimp living in the fowling material on the nearby pilings. The authors noted that 7 m away the noise spectrum level was 10 dB lower. Even so, the spectrum is substantially higher than those measured off Gladstone.

The curve labelled "Point Loma" is the average of 21 stations over shrimp beds off Point Loma, California. The curve is similar to that recorded within Gladstone harbour and its approach channel. A very different spectral shape came from averaging 23 stations in the Florida - Bahamas area. Its shape is similar to that obtained from 15 stations near Funafuti, Tuvalu; Guadalcanal, Solomon Islands; and Noumea, New Caledonia. Both curves are unlike any of the others.

The fifth curve is the average of nine sets of readings in San Diego Yacht Harbour. The authors noted that although the shrimp noise was prominent, the spectrum was quite different in shape from that obtained with the same equipment off Point Loma, just a few kilometres away. They suggest that the difference may be because the species found in this harbour are not found in outside areas. The spectral shape is also different from that for the Gladstone data

Not only do all the noise levels in Fig. 14 show significant variability, but the spectral shapes are quite different. In the present study the average fall between 630 Hz and 12.5 kHz was 17 dB, from 73 to 56 dB re $1 \mu\text{Pa}^2/\text{Hz}$ across Curtis Channel. Within Gladstone harbour and its approach channel, the fall was 14 dB, from 75 to 61 dB re $1 \mu\text{Pa}^2/\text{Hz}$. This decline exceeded some of the other data, but was similar to that for San Diego and one of the sets from near Biscayne Key.

A rapid decline was also apparent between 8 and 12.5 kHz. Across Curtis Channel the average fall was 5 dB, from 61 to 56 dB re $1 \mu\text{Pa}^2/\text{Hz}$. Within Gladstone harbour and its approach channel a fall of 8 dB occurred, from 69 to 61 dB re $1 \mu\text{Pa}^2/\text{Hz}$. This

decline also exceeded some of the other data, but was similar to that for Point Loma, San Diego and one of the sets from near Biscayne Key.

As a check on possible alterations to the spectral shape caused by equipment, a series of measurements was performed at Jones Bay, within Sydney Harbour. Here Cato and Bell (1992) reported a decrease from 77 to 74 and 71 dB re $1\mu\text{Pa}^2/\text{Hz}$ at 4, 8 and 12.5 kHz, respectively. Measurements were conducted at the same location using the Clevite CH17 hydrophone and its accompanying 2 kHz filter, and an ITC 1032 hydrophone. Signals were amplified by 40 dB using identical Maritime Operations Division preamplifiers and played into separate channels of the Sony Walkman WM60 Audio Professional Recorder. To be certain that any variations between the two hydrophones were not temporal, recordings were simultaneous. The tape recordings were then played into separate channels of an HP 3562A dynamic signal analyser. Averaging was done over 33 s when no shipping could be seen passing. Long averaging times were avoided as they invariably included the passage of shipping. Another set of readings was taken in which the tape recorder was bypassed, with the signals going from the preamplifiers directly into the signal analyser. As in the Biscayne Key data, the spectra recorded at the two different times were not identical, but were similar to that shown in Fig. 14 for the same location.

7. Conclusion

At all sites surveyed within Gladstone harbour, its approaches, and across Curtis Channel to the edge of the Great Barrier Reef, snapping shrimp produced a dominant and persistent source of noise. The noise levels were higher in the shallow waters of the harbour and its channel, than across Curtis Channel.

Differences in the level and shape of the noise spectra in the Gladstone area, compared to other areas in Australia and overseas, may be attributable to different species of snapping shrimp. More work is required to elucidate these variations, preferably with equipment recording over a broader frequency band.

The noise spectra were recorded between 630 and 12,500 Hz, but based on the measurements by Cato and Bell (1992), Widener (1967) and Everest *et al.* (1948), all of whom used equipment recording to higher frequencies, it can be expected that the transient snaps as recorded off Gladstone will have frequency components extending up to common mine hunting frequencies. Thus the snaps should be evident on a mine hunting sonar screen at all sites investigated in this study.

8. Acknowledgements

The measuring equipment was assembled and tested by Mr Neil Tavener prior to the start of the trial. Due to the rough environment to which the equipment was subjected throughout the course of the measurements, continual repairs were necessary, and these were again performed by Mr Tavener. The hydrophone was calibrated by Messrs Mark Savage and Neil Tavener. Mr Tavener also assisted in taking the sea noise measurements. The crew of the AMS Carole-S, under CPO Paul Ukhoff, provided logistical support. The Carole-S transported Mr Tavener and the author to each recording station, and provided a Zodiac and coxswain to go and take each set of readings. The crew also took depth and range and bearing readings to the Zodiac, which CPO Ukhoff used to provide the position of each recording station. Mrs Sandra Tavener provided her B&KNOISE program and offered advice on its use. Mrs Helen Lawless drew Fig. 1 and 2 from naval charts and a list of the station's positions, and digitised the data used for Fig. 12 and 13. Based on prior experience in sea noise measurements, Dr Doug Cato assisted in the interpretation of the results. Mr Jim Thompson organised RAN support for the measurements through HMAS Waterhen and offered advice on the presentation of the results as given in this manuscript.

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The distribution of snapping shrimp noise near Gladstone, Queensland

AUTHOR(S)
Mark ReadheadCORPORATE AUTHOR
DSTO Aeronautical and Maritime Research Laboratory
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ABSTRACT

The intensity of the noise generated by snapping shrimp between 630 and 12 500 Hz was measured from Auckland Wharf to the end of the dredged channel leading into Gladstone, Queensland, and on a route out across to the edge of the reef. Within the channel the noise was recorded every nautical mile; out across the reef the stations were five miles apart. Intense snapping shrimp noise was found at all sites.

The Distribution of Snapping Shrimp Noise near Gladstone, Queensland

Mark Readhead

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